# Land Mine Detection Research Center

Department of Social & Behavioral Sciences, Lincoln University, Jefferson City, MO 65101

**LU/LMDRC** **July 2006**

# Decay in AN/PSS-14 Operator Skill at 30, 60, & 90 Days Following Training:

## A Report to Dr. Alan Davison, Cooperative Agreement Manager, on Cooperative Research Contract W911NF-05-2-0029

**Robert A. Hancock**
**Land Mine Detection Research Center**
**Department of Social & Behavioral Sciences**
**Lincoln University**

## NOTICES

### Disclaimers

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. REPORT DATE** *(DD-MM-YYYY)*: 20-06-2006

**2. REPORT TYPE**: Final

**3. DATES COVERED (From - To)**: May 2005 – Jun 2006

**4. TITLE AND SUBTITLE**
Warfighter Research in Mine Detection: Decay in AN/PSS-14 Operator Skill at 30, 60, & 90 Days Following Training

**5a. CONTRACT NUMBER**: W911NF-05-2-0029

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**6. AUTHOR(S)**
Robert A. Hancock

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lincoln University
820 Chestnut Street
Jefferson City, MO 65101

**8. PERFORMING ORGANIZATION REPORT NUMBER**

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
U.S. Army Research Laboratory Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBERS**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
Recent evaluation of the PSS-14's deployment in support of ongoing military operations indicates that poor retention of operator skill is a problem that can compromise the effectiveness of the mine detection system, endanger the success of countermine operations, and jeopardize the personnel involved. Experiment 1 examined the rate of decline of operator skill over intervals without practice (retention intervals of 30, 60, & 90 days). A decline in the proportion of mine simulants detected was observed with as little as 30 days without practice. Analysis of components of the operator skill revealed differential rates of decline of different skill components. Results of this study can provide guidelines for scheduling maintenance or refresher training that will allow the operator skill to be restored to maximal performance levels. Experiment 2 developed and tested inexpensive land mine simulants to support maintenance or refresher training at decreased costs.

**15. SUBJECT TERMS**
AN/PSS-14, mine, training, retention interval, probability of detection

| 16. SECURITY CLASSIFICATION OF: a. REPORT | b. ABSTRACT | c. THIS PAGE | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | SAR | | Robert A. Hancock |
| | | | | | 19b. TELEPHONE NUMBER (*Include area code*) 573-681-6194 |

**Standard Form 298 (Rev. 8/98)**
**Prescribed by ANSI Std. Z39.18**

## Contents

## List of Figures

## List of Tables

## Executive Summary

*Purpose*

The AN/PSS-14 hand-held stand-off mine detector theoretically represents a significant advance in countermine capability over the AN/PSS-12 metal detector due to an improved metal detect and the addition of a ground penetrating radar sensor. However, Maurer (2003) found a decline in operator performance with the AN/PSS-14 30 days post training. The purpose of the research reported here is to: 1. identify what the decrements in operator performance are and how quickly they occur and 2. develop lost cost low metal land mine simulants to better enable the U.S. Army to conduct training.

In Experiment 1, individuals were trained with an improved AN/PSS-14 Program of Instruction (POI), had their skills tested at the end of that training (the Exit Test), and then groups of those individuals had their skills re-tested at retention intervals of 30, 60, or 90 days (the Retention Test). This allowed the researchers to identify how quickly AN/PSS-14 skill components deteriorated and what specific components of AN/PSS-14 operations showed the greatest decline. In Experiment 2, a set of low metal land mine simulants with substantially lower costs than current simulants was developed and validated.

*Findings – Experiment 1*

At the end of training, Trainees had a median land mine simulant detection rate of 100% and a median clutter detection rate of 93%. Despite the high rate of detection only about 20% of the clutter found was identified as clutter - meaning that almost 80% of the time operators identified clutter as a mine. Although clutter type had no significant effect on the likelihood of detection it did have an effect on the probability of clutter rejection. Some types of clutter (nails and wire) were much more likely to be correctly identified as clutter than other types (tacks, M-60 links, M-60 brass, and barbs from barbed wire).

Retention Test performance was significantly worse than Exit Test performance. After just 30 days, there was a significant decrease in the proportion of mine simulants detected. The decrease in simulant detection can be attributed largely to a degradation of metal detection (MD) technique, which showed significant declines 30 days after training and further significant declines after 60 days. The decrease in simulant detection on the Retention Test was particularly noticeable for a specific type of mine simulant, the Anti-Personnel Low Metal or APLM simulant whose metal halo overlapped the metal halo of nearby clutter.

*Findings – Experiment 2*

A set of low metal land mine simulants was produced at 1/10$^{th}$ the production cost of current simulants. These simulants were tested for robustness of ground penetrating radar (GPR) response from the AN/PSS-14. All of the low cost simulants produced better GPR response from the AN/PSS-14 than the currently deployed higher cost simulants. The improved GPR response by these low cost simulants is particularly important because in the course of Experiment 1, current U.S. Army simulants occasionally failed to produce any GPR or produced inconsistent GRP. These GPR failures were particularly problematic because trainees, putative Soldiers, appeared to lose confidence in the system when existing simulants failed to produce any GPR response or produced only an intermittent GPR response.

*Conclusions/Recommendations*

1. There are numerous possible reasons for operators' failure to reliably reject clutter. One, the POI may not be teaching correct GPR technique. Two, the participants might not have been able to execute correct technique. Three, there may be inherent limitations in the capabilities of AN/PSS-14 to reject certain types of clutter. Current data do not allow for the determination of which of these possibilities is the most likely. Given the importance of clutter rejection for maximizing the potential of the AN/PSS-14, this problem needs further investigation, quickly.

2. The rapid forgetting of MD technique and the consequences of poor MD technique indicate that both the Certification criteria and the POI implemented in this study need significant change. Training lanes should include more Anti-Personnel Low Metal mine simulants and more low metal simulants whose metal halos overlap the metal halos of nearby clutter. The POI for the AN/PSS-14 should have increased emphasis on MD technique and detection of low metal simulants with halo overlap. Low metal mines with metal halo overlap with clutter are the most challenging mine simulants and mines to detect accurately. Soldiers (trainees) should be better prepared to meet the challenge posed by such mines.

3. The availability of low cost mine simulants should be a significant boost to training and refresher training by reducing training costs. The greater reliability of these simulants in producing GPR is also an important advance so that trainees/Soldiers will develop confidence in the system. However, it is critical that systematic data comparing the response of the AN/PSS-14 mine detector, particularly GPR response, to simulants and actual threat mines mines be completed. If simulants produce stronger MD and/or GPR responses than actual threat mines, then training conditions will not adequately prepare trainees/Soldiers for operational conditions.

# 1. General Introduction

The AN/PSS-14 represents a significant advance in countermine capability over the currently-fielded AN/PSS-12 metal detector (Santiago, Locke & Reidy, 2004). Initial operational tests showed that the AN/PSS-14 exhibited superior mine detection capabilities - provided operators are well-trained. In addition, the AN/PSS-14 performs well in environmental conditions that make the AN/PSS-12 ineffective, particularly environments with conductive soil.

Given the potential of the AN/PSS-14 demonstrated in the developmental tests of 2002 and immediate operational needs, the U.S. Army Requirements Oversight Committee accelerated the development and fielding of this system. Early production units were deployed in support of Operations Enduring Freedom and Iraqi Freedom.

On-site assessment of AN/PSS-14 performance was conducted in Afghanistan in the spring of 2003 to address issues that arose about the system's capabilities and use in the operational environment (Maurer, 2003). This assessment reported that under operational conditions:

1. The AN/PSS-14 was performing within the ORD and manufacturer's designed specifications.
2. The AN/PSS-14 could detect very low metal mines, including the YM-1, from flush to operation depths of 4 inches overburden.
3. The AN/PSS-14 could detect low metal mines in close proximity to metal clutter and in metal laden soils.
4. Sappers in Afghanistan were confident that they could detect low metal mines using the AN/PSS-14.
5. Sappers have the skills and knowledge to successfully and safely detect mines using the AN/PSS-14.

These favorable conclusions were subject to the condition mentioned above - "provided operators are well-trained." Two additional observations raised concern. First, the majority of operators' techniques were deficient, resulting in dangerously low detection rates (73.6) following a month without system use. Second, refresher training delivered immediately afterward restored detection performance to outstanding levels (98.6) and increased the operators' confidence in their countermine capabilities with the AN/PSS-14. The clear implication is that operators' skills had deteriorated in the interval between New Equipment Training (NET) and operational use of the AN/PSS-14.

An extensive scientific literature (Healy, 1995; Fan, 1987; Rose, Gragg, Austin, Ford, Doyle, & Hagman, 1985; Shields, Goldberg, & Dressel, 1979) shows that without practice, as the time interval (or retention interval) between skill training and skill performance increases, skill proficiency decreases. When that skill is landmine detection, this decrease in skill proficiency leads to casualties. A single error, i.e., a single failure to detect a mine, jeopardizes the soldier engaged in countermine operations, those in close proximity to that soldier, and/or those who follow in that soldier's footsteps. Recent casualties sustained in countermine operations in support of Operation Enduring Freedom have been attributed to skill decay resulting from the

extended time period between original training on new countermine equipment and operational use.

The evaluation of the AN/PSS-14's deployment in support of ongoing operations indicated that poor retention of operators' skills is a multi-facited problem that can compromise the effectiveness of the system, endanger the success of countermine operations, and jeopardize the personnel involved (Maurer, 2003). Solving the problem of operator decrement in the effective use of the AN/PSS-14 involves the following: (1) improving training to prevent or minimize such decrements from occurring; (2) identifying what the decrements are and when they occur; and (3) developing interventions to restore performance to requisite levels as efficiently and as economically as possible through refresher training. With regard to the first problem, improving training, Schweitzer, Davis, Pettijohn, Clark, Davison & Stasewski (2006) conducted research on the Program of Instruction (POI) for the AN/PSS-14. Schweitzer et al. made a number of recommendations for the improvement of AN/PSS-14 training to The Training and Doctrine Command (TRADOC). Subsequently, the Directorate of Training and Leader Development (DOTLD) of the U.S. Army Engineer School adopted those recommendations for NET training for the AN/PSS-14. While the DOTLD accepted those recommendations, they were not fully implemented in the training the U.S. Army was receiving under a contract with the manufacturer. The training used in this research necessarily replicated the training provided under the Army contract. Thus, it did not include many of the recommendations that had been made to improve AN/PSS-14 training.

Improvement of training alone is not sufficient to address all of the problems identified by Maurer (2003) for AN/PSS-14 deployment. In Experiment 1 conducted here, the second part of solving the problem was the primary focus. In Experiment 1, individuals were trained with the improved AN/PSS-14 POI, had their skills tested at the end of that training, and then groups of those individuals had their skills re-tested at retention intervals of 30, 60, or 90 days. This allowed the researchers to identify how quickly AN/PSS-14 skill components deteriorated and what specific components of AN/PSS-14 operations showed the greatest decline. In Experiment 2, low cost SIMs to support both initial training and refresher training (problem 3 above) were developed. A validity test has been developed for SIMs and partially executed on the SIMs developed.

## 2. Experiment 1 - Method

### 2.1.Research Design

The research conducted here resulted in a detailed understanding of skill proficiency/performance decrements in mine detection using the AN/PSS-14 following partially improved U.S. Army training (Schweitzer et al., 2006) at retention intervals of 30, 60, and 90 days. This was accomplished through a 3 x 2 mixed-model factorial design. Research participants/trainees completed an AN/PSS-14 field certification test at two different times, the Time of Test variable. The levels of Time of Test were immediately following certification training, the Exit Test, and at the end of one of three retention intervals, the Retention Test. For different groups of research participants, the Retention Intervals was 30 Days, 60 Days, or 90 Days following the Exit Test.

Due to sample size constraints, three additional within subject factors which, *a priori*, were deemed to be important to the detection of mines, i.e., Mine Composition (high vs. low metal), Mine Size (anti-tank vs. anti-personnel), and Halo Overlap (absence or presence of an overlapping metal halo from nearby clutter) could not be fully balanced in a 3 x 2 x 2 x 2 x 2 mixed-model factorial design. Therefore analyses of these additional factors were undertaken in isolation (3 x 2 x 2 mixed-model factorial designs) and in pairs (3 x 2 x 2 x2 mixed-model factorial designs). Analyses which showed signficiant effects are presented below.

Policies for the protection of human subjects as prescribed in Army Regulation 70-25 and the Department of Health and Human services were adhered to in the research protocol and conduct of this research.

### 2.2 Research Participants/Trainees

Fifty-six males with U. S. Citizenship between the ages of 18 and 35 were recruited by visits to area high schools, colleges, and National Guard installations. In addition, an e-mail describing the study was distributed to area ROTC units. Three participants/trainees withdrew before completing the week of training for reasons unrelated to the training. A fourth individual completed the training but was unable to return for retention testing. Analyses of training data was unaffected by exclusion of this individual and data reported does not include him.

### 2.3 Research Apparatus[1]

The AN/PSS-14 is a hand-held, stand-off mine detector that can detect both high metal and low metal mines (see Figure 1) in mineralized soils. The Sensor Head contains both a metal detector (MD) and ground penetrating radar (GPR) unit. Signals produced by these units are analyzed by the Electronics Unit which in turn produces auditory signals in the Earpiece and an external speaker mounted in the Electronics Unit. Auditory tones that can differ in loudness and pitch are generated by the MD in response to metal objects. A "beep" which is constant in pitch and loudness and readily distinguishable from MD tones is produced by the Electronics Unit in

response to GPR signals *only* when detectable metal is also present. Major components of the AN/PSS-14 are its battery case and cable (mounted on a belt worn by the operator), the electronics unit, earpiece and cable, control grip, wand assembly, and sensor head.

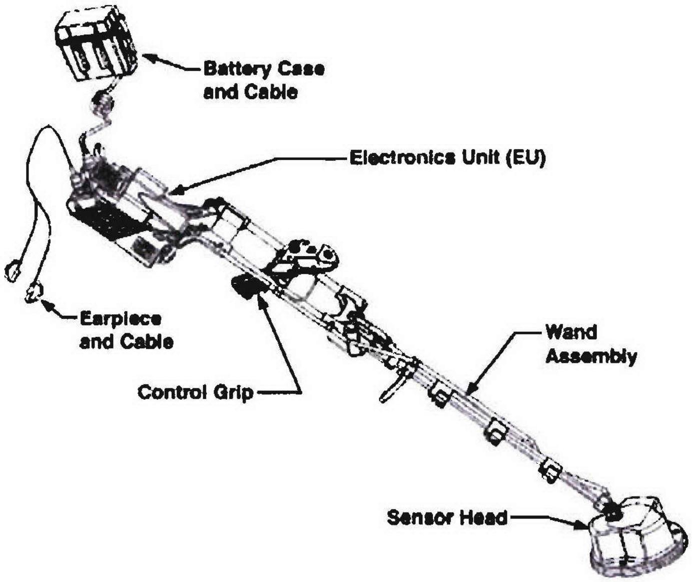


**Figure 1 AN/PSS-14.**

> The AN/PSS-14 uses two different sensors for the detection of mines – ground penetrating radar (GPR) and metal detection (MD). Each sensor returns a unique audio signal and can be heard individually or in combination with the other. GPR can locate objects up to six inches deep in the soil by transmitting radar waves into the ground and analyzing the reflected waves. GPR detects objects because of the change in density from the surrounding soil. MD induces a secondary magnetic field in nearby metal objects. If the secondary magnetic field is strong enough (dependent upon the composition and quantity of the metal) for the MD processor to detect, the processor will produce an auditory signal indicating the presence of metal. If metal is detected and an irregularity is detected in the reflected GPR wave pattern, the GPR processor will also produce an auditory signal. In other words, GPR will sound only if metal is present. (Schweitzer et al., 2006, p 6).

Both MD and GPR units require "training" or calibration to the environmental conditions before successful operation. The calibration process requires a number of ordered steps. Table 1 shows the steps necessary to complete the calibration of the AN/PSS-14 and make it ready for operation. Step 1 insures that the system has been turned on properly and is working normally. Step 2 eliminates interference from other radio signals in the area including other systems. Step 3 eliminates soil mineralization effects. Step 4 establishes a baseline level for the GPR to filter soil scatter. Step 5 verifies that calibration procedures have been conducted properly against a test piece or known SIM target. Once the detector is successfully calibrated, the operator is prepared to search for mines.

Detection of mines requires three sequential skills: Lane Sweep technique, MD investigation, and GPR investigation. Auditory signals alert the operator when a target is present. The operator first finds the origin of the metal signature and then uses the GPR signal to establish whether the target is a mine (returns a GPR signal) or clutter (no GPR signal).

Proper Lane Sweep technique, the first skill taught and the first in sequence of system operation, insures that every square inch of a lane is correctly investigated for mines. The operator's movement must allow him to cover the whole lane. Proper Lane Sweep technique requires that: (1) the Sensor head be parallel to the ground as closely as possible – head height should never exceed 2 inches; (2) the Sensor head must be moved across the lane in a straight line; (3) the Sensor Head must traverse the lane at a constant speed between 1.0 to 3.6 ft/sec; (4) the Lane Sweep must extend laterally one-half of the sensor head width outside the lane; and (5) the Lane Sweep must advance forward one-third of the sensor head width to begin the return sweep. The purpose of the sweep is to receive an "alert", i.e., a signal that must be investigated. After receiving this alert, the Soldier/Trainee must switch from Lane Sweep mode to a localization mode in which a target is investigated. The first step in localization is to verify the alert signal. If the signal is not repeated, the operator continues to sweep the lane. If the alert signal is confirmed the operator must pinpoint the location of the target with MD techniques and then verify the target with GPR techniques.

Once a target has been identified, a MD footprint must be developed. The footprint area is the entire area in which a continuous MD signal is being generated. For MD investigation, the mine detector operator must move the detector head in a semi-circular fashion around the target, establishing a small spiral pattern to find the outer boundaries of the signal or halo (see Figure 2) of the target or targets. This boundary can be established most easily by the onset (presence vs. absence) of the MD signal. The Soldier/Trainee places poker chips at the 3, 6, 9 o'clock and other boundary positions of the target signal to help him visualize the target metal footprint. Once the footprint is built, either by chips or through a mental image, the operator lays a single chip to declare the center of the target based on its metal signature. Figure 2 represents the case of a symmetrical metal halo with a single target.

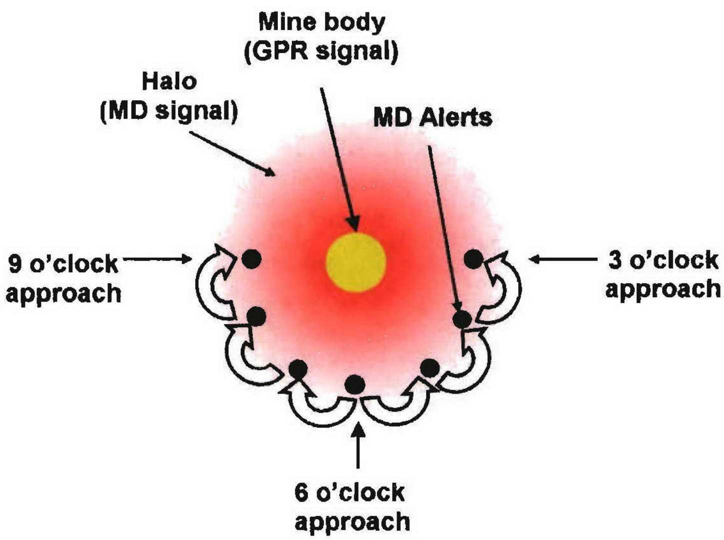

**Figure 2 MD investigation with a single target.**

With asymmetrical halos, the task is considerably more difficult because there may be areas where the metal signals from two metal sources overlap. When metal signals overlap, the 3, 6, and 9 o'clock positions cannot all be established by the onset (presence vs. absence) of the signal. Instead, in the area of overlap, centering positions must be established by changes in MD signal tone and intensity. In Figure 3 below, one can see that the 3 o'clock position for Target 1 which is also the 9 o'clock position for Target 2 must be identified by changes in the MD signal tone and/or intensity produced between the target centers.

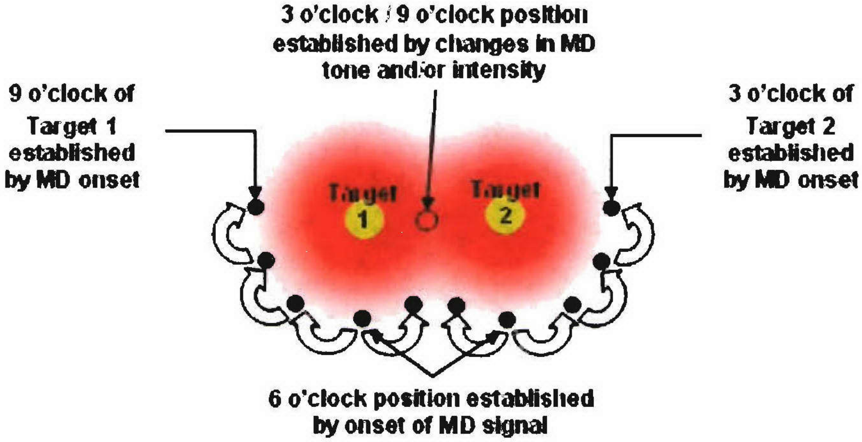


**Figure 3 MD investigation with two targets with overlapping halos.**

Once a proper target center has been established, the target is identified or verified with the GPR. Proper GPR technique, called GPR "short sweep", utilizes a normal sweeping motion with respect to speed and position, but is traversed only within the suspected mine's MD footprint. GPR is used first to verify that a target is in the ground – many commonly found high metal objects, such as a nail or other metal fragment, are often small enough that the GPR will not detect them, thus allowing an operator to reject such items as clutter, i.e. not a mine. The second purpose of GPR is to verify the position of the declaration. The metal content of most mines is either in the center (as in low metal mines like the M14) or evenly distributed throughout the mine (as in metal mines like the M15).

> The introduction of clutter to an operator's "vocabulary" of known targets is confusing at first. Clutter generates subtly different audio signals (in terms of frequencies and amplitudes) than those produced by the mine simulants used in training. Clutter also occurs more frequently than mines do, causing more frequent interruptions in an operator's sweep and allowing more opportunities for error when sweeping is resumed (such as improperly sweeping past an anti-personnel low metal (APLM) type mine and not detecting it). Often clutter sounds similar to a mine, which builds frustration in the operator and precipitates hasty center declarations or multiple target declarations instead of a single,

> carefully investigated, confident mine declaration. Isolated occurrences of clutter are not the only troubles introduced in tactical lanes – clutter in proximity to mines initially bewilders many operators. (Schweitzer et al., 2006, p 8).

Further considerations are the relative size of the metal halo (the area detected by MD investigation) and the mine body (the area detected by GPR investigation). In high metal mines the MD halo will always exceed mine body (see Figure 4 on the left) but the reverse may be true with low metal mines (see Figure 4 on the right). Figure 4 shows just such an arrangement. On the left is a high metal mine, the metal halo (shown in red) for the high metal mine is about 12 inches from the center of the mine, whereas the GPR footprint (shown in yellow) occurs close to the mine's edge. The darkness of the red shade represents the loudness of the metal signal. On the right, the metal halo is a small spot (shown in red) about 1-2 inches from the center of the mine, whereas the GPR footprint (shown in yellow) is larger than the metal halo.

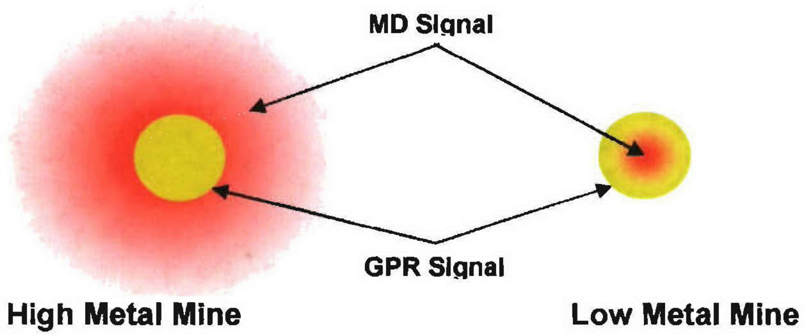


**Figure 4 Signal halos in high and low metal mines.**

Finally, based upon the presence or absence of a GPR signal, the operator makes a decision about the investigated target. Clutter is indicated by the absence of a GPR signal; a mine is indicated by the presence of a GPR signal.

## 2.4 Training Site

Training was conducted at the training facility of the Lincoln University Land Mine Detection Research Center. This training facilty has three components: a classroom complex, a detector sweep training area adjacent to the classroom complex, and a tactical training area. The classroom complex and the adjacent sweep training area were on loan from other Lincoln University units. The Tactical Training Area is dedicated to the Land Mine Detection Research Center.

The Tactical Training Area consisted of eighteen 1.5 M x 19 M tactical training lanes and six 2 M x 5 M sterile sand pits. Figure 5 shows the layout of the Tactical Training Area; the tactical lanes run in an East-West direction.

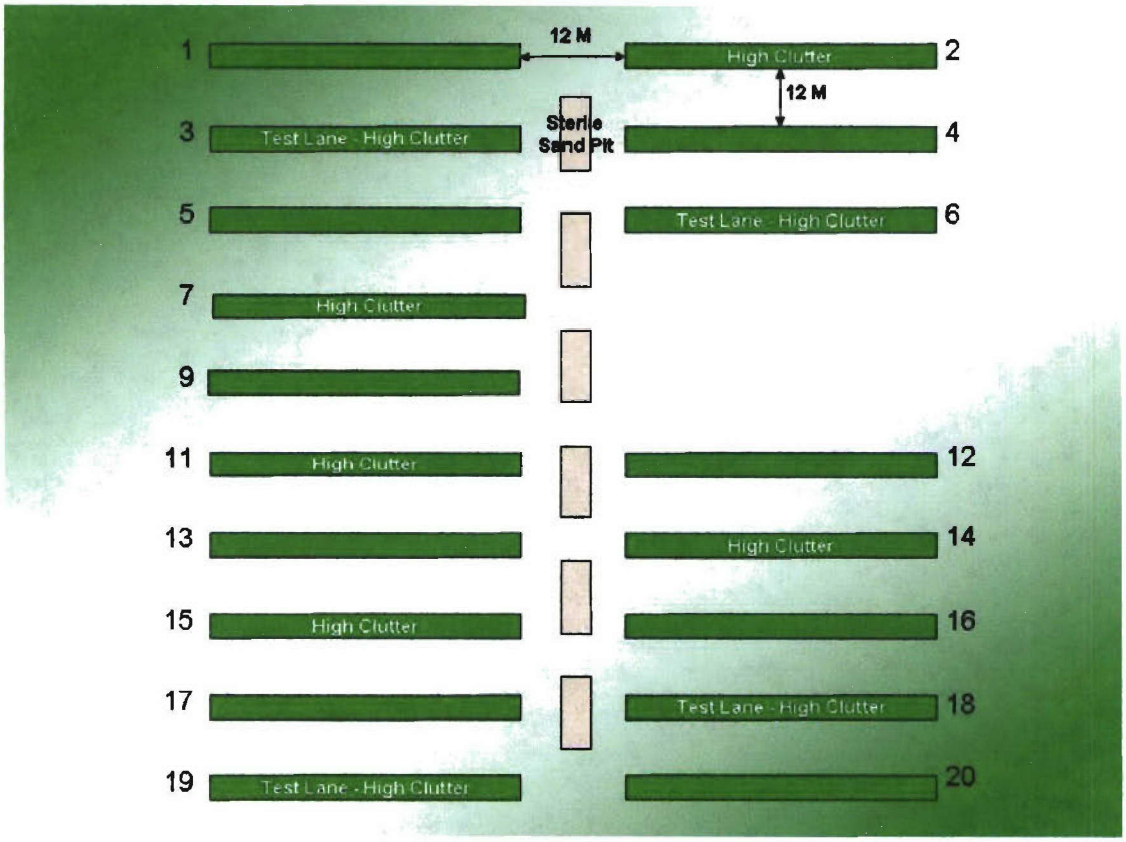


**Figure 5 Layout of Tactical Training Area with distances between tactical lanes noted (not drawn to scale).**

Tactical lanes were 1.5 M wide by 19 M long. Each lane end consisted of a 2 M long sterile area in which the AN/PSS-14 could be ground balanced and GPR trained. The middle 1.5 M wide x 15 M long section was divided into 10 cells. Each 1.5 M x 1.5 M cell was mapped to a coordinate grid 1-10 wide and A-J long. All targets, both mine simulants and clutter, were placed in cells at grid coordinates, only.

All lanes had 9 mine simulants (SIMs): two SIM 6s, one SIM 9, SIM 12, SIM 20, SIM 25, SIM 30, M15 SIM, and M16 SIM. SIMs were arranged with no more than one SIM per cell, leaving one of the 10 tactical cells without a SIM. In each lane, four or five psuedo-randomly selected simulants were placed in proximity to a single piece of clutter such that the MD halos overlapped or adjoined one another.

Nine of the lanes were Low Clutter Lanes (tactical lanes 1, 4, 5, 9, 13, 16, 17, and 20) with 15 pieces of clutter placed at grid coordinates. The other nine lanes were High Clutter Lanes with 30 pieces of clutter. Four lanes were chosen for certification test lanes (see below, section 2.5 Procedure). Clutter consisted of the following items: M16 brass (i.e, an expended M16 round), M-60 link, 10 cm barb-wire segment with a bard in the middle, 12 penny nail, roofing tack, barb-wire barb, and, in rare instances, natural clutter. (Tactical lanes and the area around them had been cleared of natural clutter in advance of the study. In a very few cases, not all natural clutter

could be removed. In those cases, the natural clutter was noted and mapped to the nearest grid coordinate. Since the completion of this study, on-going training site maintenance has resulted in the replacement of all natural clutter with controlled clutter).

All targets were carefully buried precisely at grid coordinates at fixed distances below the lane surface. All clutter was buried 1 inch below surface. The SIM 6s, 9, and 12 were buried 1 inch (to top of target) below surface. The SIM 20, 25, and 25 were 2.5 inches cm to top of target below surface. The M16 SIM was 2 inches and the M15 SIM was 3 inches to top of target below surface.

## 2.5 Procedure

Research Participants were assigned by availability into one of 6 training weeks. Due to time constraints, training week and Retention Interval were confounded. Participants in training weeks 1 and 2 were the 90 day Retention Interval group; weeks 3 and 4, the 60 day Retention Interval group; and weeks 5 and 6, the 30 day Retention Interval group with two exceptions. Two participants from training week 5 missed their initial retention test date and were reassigned to retention test dates that resulted in 60 day retention intervals.

The AN/PSS-14 certification training Program of Instruction (POI) consisted of four consecutive days of training followed by, on a fifth consecutive day, certification testing. Table 2 shows a day by day outline of the POI as well as the location of the training components.

Day 1 consisted of approximately 3 hours of classroom instruction on the theory of operation, start-up procedures, and operating controls of the AN/PSS-14. This is followed by approximately 2.5 hours of instruction and practice in detector sweep technique in a designated Sweep Training Area consisting of a Sweep Monitoring system on a concrete pad and three adjacent 1.5 M x 10 M level grass lanes.

Initally, sweep technique was taught and practiced without turning on the detector electronics, i.e., the detector is inoperable, or "dry sticking". This "dry sticking" was designed to be accompanied by feedback from an electronic Sweep Monitoring System or SMS (see Schweitzer et al., 2006, for a more detailed description of its operation). In addition, the improved POI called for daily practice with the SMS to improve sweep technique. However, owing to repeated system failures, use of the SMS was restricted to Day 1, on which it operated intermittently.

Sweep training was followed by trainer demonstrations of AN/PSS-14 start-up and calibration procedures, followed by research participants practicing those procedures. Day 1 ended with trainer demonstrations of the MD footprints of the six mine simulant types and selected clutter employed in training. These demonstration took place in the sand pits of the Tactical Training Area.

Day 2 began with a review of the preparation for operation (PMCS) of the AN/PSS-14 and its start-up procedures. This was followed by additional footprint demonstratons with an emphasis on targets with overlapping MD halos. Day 2 ended with research participants practicing start-

up procedures, followed by practice with MD investigation and GPR Short Sweep over identified targets.

Day 3, following a PMCS review, consisted of sweeping 2 – 3 low clutter, tactical lanes; number of lanes swept depended upon weather conditions and participant performance. Participants were required to mark all target centers (mine simulants and clutter) with colored poker chips according to the following format: red for APLMs, yellow for ATLMs, blue for APMs, orange for ATMs, and white for clutter.

Participants were given feedback for gross errors in sweep, MD, and GPR techniques during lane sweeps. Following completion of a lane, if a research participant missed a significant mine simulant (SIM) or made a signficant error in SIM identification, e.g., marked an ATLM with an orange chip indicating an ATM, the research participant re-swept the portion of the cell that contained that SIM. Research participants were rotated so that no participant swept the same low-clutter lane more than once.

Day 4, following a PMCS review, consisted of sweeping 2 - 4 high clutter, tactical lanes; number of lanes swept depended upon weather conditions and participant execution. Participants were required to mark all target centers, mine simulants and clutter) with colored poker chips according to the following format: red for APLMs, yellow for ATLMs, blue for APMs, orange for ATMs, and white for clutter.

Participants were given feedback for gross errors in sweep, MD, and GPR techniques during lane sweeps. By Day 4, the frequency of such errors was so low that most participants completed lanes uninterrupted, which accounts for no decrease in lanes completed despite a significant number of targets requiring investigation. Following completion of a lane, if a research participant missed a significant mine simulant (SIM) or made a signficant error in SIM identification, e.g., marked an ATLM with an orange chip indicating an ATM, the research participant re-swept the portion of the cell that contained that SIM. Research participants were rotated so that no participant swept the same high-clutter lane more than once. (Due to experimenter error, one participant repeated a high clutter lane.)

On Day 5, research participants completed a standard multiple-choice test and a Field Performance Test. The Day 5 Field Performance Test is referred to as the Exit Test in the results sections. The Field Performance Test involved sweeping a high clutter tactical lane which the research participant had not previously encoutered. Only four tactical lanes were employed on the Field Performance Test (identified in Figure 5 as "Test Lane") to reduce variability between research participants. Participants were required to mark all target centers, mine simulants and clutter with colored poker chips according to the following format: red for APLMs, yellow for ATLMs, blue for APMs, orange for ATMs, and white for clutter. Participants were given no specific feedback on their Field Performance Test or Exit Test other than that they "passed".

A Retention Test Day occurred on a Saturday either 28, 58, or 88 calendar days following Day 5. These Retention Test Days are nominally the 30, 60, and 90 day retention intervals. Research participants arrived at the training center at 0800 hours, received 30 minutes of refresher training, completed an abbreviated ASVAB practice test, tested for proper start-up procedures, completed

4 foot print-drills, and were retested on the identical tactical lane they were tested on the Day 5 Field Performance Test.

Before, retesting on the tactical lane, all start-up errors were corrected. This ensured that the AN/PSS-14 was operating properly and performance decrements on the Retention Test were due to operator error and not detector system malfunction. Retesting participants on the same tactical lane insured that any changes in performance would not be due to differential tactical lane difficulty. Participants were again required to mark all target centers, mine simulants and clutter, with colored poker chips according to the following format: red for APLMs, yellow for ATLMs, blue for APMs, orange for ATMs, and white for clutter.

# 3. Experiment 1 - Results

## 3.1 Introduction

The primary task of an operator using the AN/PSS-14 is to find mines or mine simulants. Secondarily, the task of the AN/PSS-14 operator is to reject clutter. Both of these tasks require that AN/PSS-14 operators find all targets. The probability of detecting targets is primarily dependent on proper Lane Sweep technique. Proper MD technique is required to properly center targets to allow for accurate GPR technique. For example, an APLM that is detected but improperly centered may not be correctly identified as a mine because the GPR short sweep used to detected the mine body is not occuring over the mine body. Proper GPR technique is required for correct indentification of targets. Therefore, although the detection of mines is the single most important task of the AN/PSS-14 operator, the probability of detection of mine simulants is a measure sensitive to errors from any of the three techniques. Therefore, three dependent measures were analyzed: target detection, target centering, and target classification.

A mine simulant was considered detected if a non-white poker chip was placed on the body of the target. Therefore, mine simulant detection failures could occur for three reasons: 1. failure to find the target completely, i.e., a Sweep Technique error; 2. placement of the poker chip too far from target center, an MD technique error; or 3. incorrect target identification, i.e., a GPR technique error. At the end of training, there were no instances of incorrect identification of detected mine simulants, i.e., no mine simulant was called clutter. All mine simulant detection errors were either due to a failure to find the target or a distance error (poker chip placement too far from target center). On the other hand, incorrect identification of clutter was frequent and clutter dependent (see below). These data suggest that, at the end of training, GPR technique may be improper but corrected for by a strong decision bias to call any detected target a mine simulant. Therefore, these data may not be able to provide information about degradation in GPR technique.

As an assessment of MD technique, the actual distance between the target center and the closest edge of a poker chip placed to mark that target was measured to the nearest 0.25 inches. And, finally, although a record was kept of the exact target type identified (i.e., color of the poker chip placed), for the purposes of this report, SIMs were scored as correctly identified if marked with any non-white poker chip and clutter was scored as correctly identified if marked with a white poker chip.

## 3.2 Training/Certification Results

U.S. Army AN/PSS-14 Certification has two components, a multiple-choice test over AN/PSS-14 operation and a field test. The field test requires trainees to detect 9 out of 9 simulant targets buried in a training lane; however, individuals who fail to find 9 out of 9 targets on an initial sweep of a field test lane are given a second opportunity to pass the field test on a second lane. As Schweitzer et al. (2006) noted, trainers may be assigning trainees to less difficult mine lanes on retest to assist those trainees in passing the certification field test. Because the research

design called for trainees to complete their retention test on the same lane as their exit/certification test and to equate experience with the exit/certification test across retention groups, the research protocol did not allow for retesting of trainees who failed to find 9 out of 9 simulants. In addition, to maintain maximum subject morale for retention testing, all trainees were told that they "passed" the field certification test and were asked to return for the retention test. Based upon the results of Schweitzer et al. (2006), we anticipated that trainees in this study would perform generally well, missing few if any mine simulants during the exit/certification test and those trainees in this study that did not pass the field test initially, certainly would on retest.

As expected, most trainees performed very well on the exit/certification field test. The median proportion of Mine Simulants detected was 1.00, that is, 9 out of 9 simulants were detected, with the 25th percentile equal to 0.889, that is, 8 of 9 simulants were detected. Figure 6 presents a box plot of the proportion of mine simulants detected by trainees during the exit/certification field test. Four of the trainees clearly met Tukey's (1977) criteria for being outliers and have been excluded from all other analyses[2]. That is, the performance of these four trainees suggests that they would have failed on a retest and, therefore, provide a highly biased baseline against which to test for retention of mine detection skill. Review of researcher notes on comments made by these individuals during training and exit test revealed that these individuals had low commitment to the research goals.

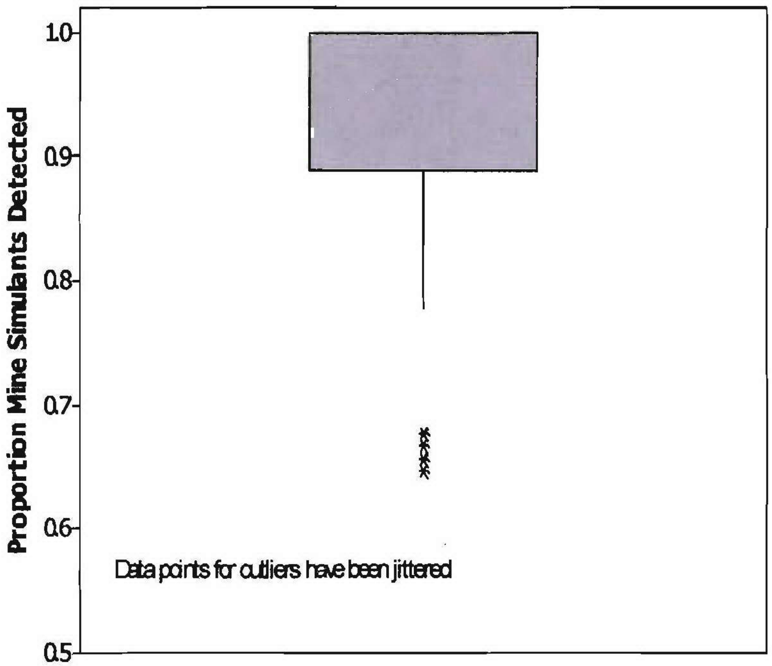


**Figure 6 Box plot of proportion of mine simulants detected at the end of training.**

### 3.3 Other Significant Training Results

Trainees in this study were graded on aspects of performance typically ignored in certification testing, the most important of which was clutter rejection, that is, the frequency with which

trainees correctly identified detected clutter as clutter. Figure 7 shows clutter detection rates and clutter rejection rates for Trainees at the end of training. Clutter detection is the proportion or probablity that clutter in the ground is found. Clutter rejection is the proportion or probability that found clutter is identified as clutter instead of misidentified as a mine simulant.

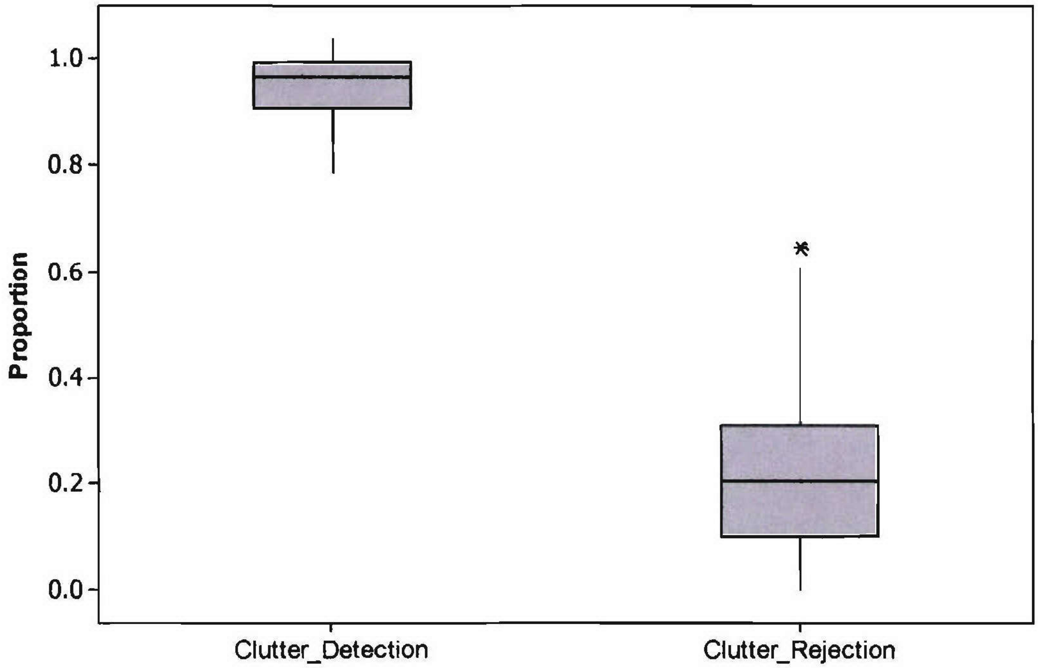


**Figure 7 Box plot of proportion of clutter detected and clutter rejected at the end of training.**

The median proportion of buried clutter detected was 0.96, that is, clutter was detected about 96% of the time. Clutter was detected, as would be expected, with a frequency about equal to that of mine simulants. Of the detected clutter, a median proportion of 0.207 was correctly identified as clutter, that is, about 80% of the time clutter was identified as a mine simulant. One should note that clutter rejection was skewed such that a few individuals had high rates of clutter rejection while most individuals had low rates of clutter rejection. The 25$^{th}$ percentile for clutter rejection was 0.10; the 75$^{th}$ percentile was 0.31.

Clutter type had no significant effect on the likelihood of detection. As Figure 8 shows, the proportion of clutter detected was virtually invariant with respect to clutter type.

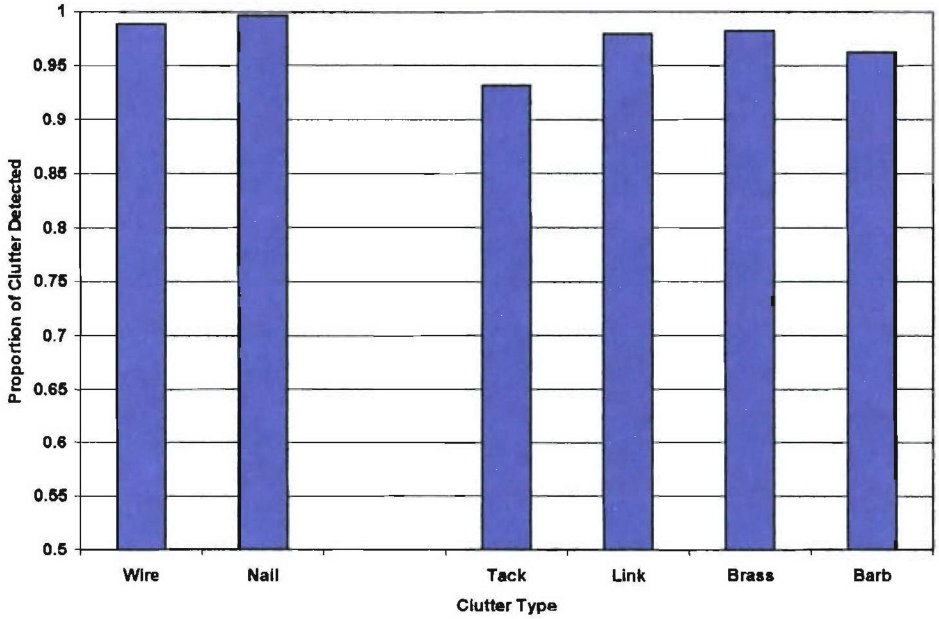


**Figure 8 Proportion of clutter detected by clutter type.**

However, clutter type had a significant effect on the propobility of clutter rejection. As Figure 9 clearly shows, wires and nails were much more likely in both statistical and practical terms to be correctly identified as clutter than tacks, M-60 links, M-60 brass, barbs from barbed wire.

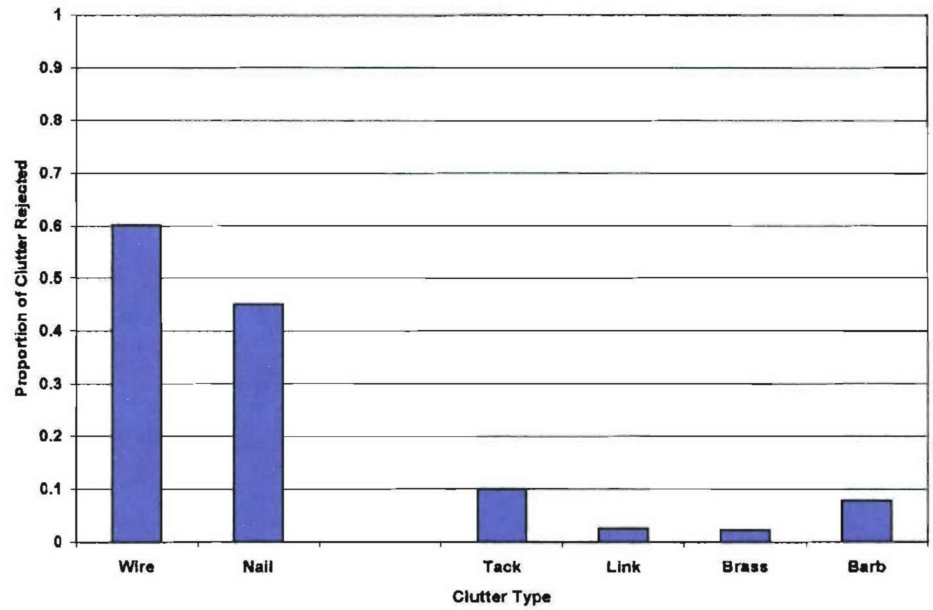


**Figure 9 Proportion of clutter rejected by clutter type.**

## 3.4 Retention Results

The primary issue for Experiment 1 was the rate of forgetting for mine detection skill using the AN/PSS-14. This rate of forgetting is revealed by decreases in the proportion of detected mine simulants. Figure 10 shows the mean proportion of mine simulants detected by Retention Interval (30, 60, or 90 days) and Time of Test (Exit vs. Retention). Table 3 shows means, sample sizes, and standard errors for this figure.

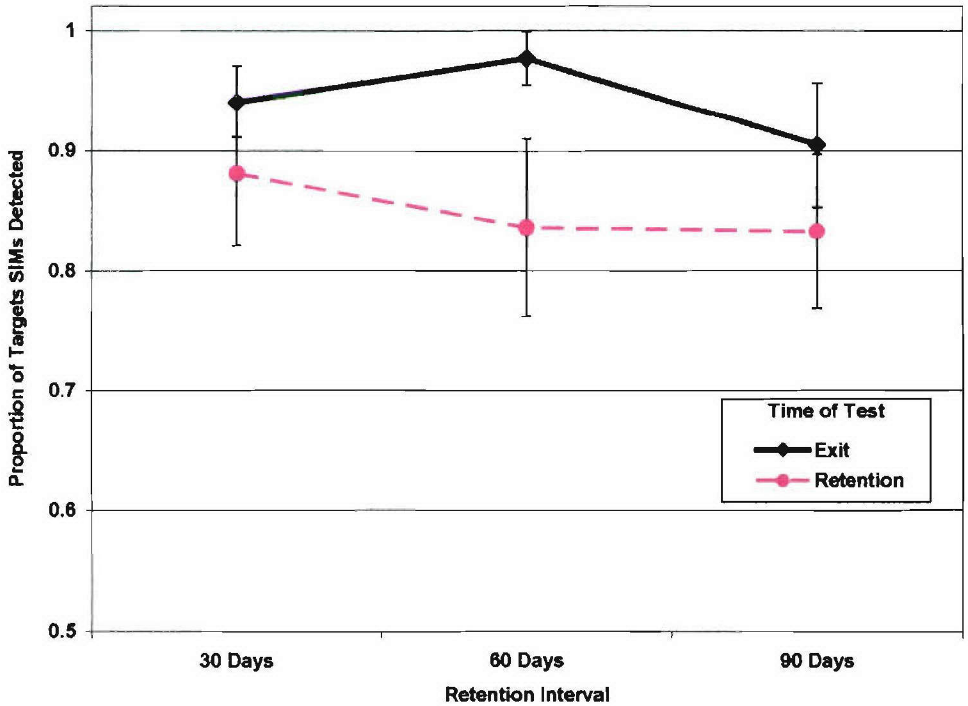


**Figure 10 Mean proportion of mine simulants detected by time of test and retention interval (with 95% confidence interval bars).**

Consistent with the visual impression, ANOVA (see Table 4) revealed significant decrements in proportion of mine simulants detected due to Time of Test ($p < .0001$). Overall, Retention Test performance was worse than Exit Test performance. The differential effect of retention interval, as evidenced by the Retention Group x Time of Test (Exit vs. Retention) interaction, was not significant ($p > 0.21$).

Consistent with Exit Test results, Retention Test mine simulant detection errors usually represented a failure to find the simulant (a Sweep technique error) or a failure to accurately identify the center of the simulant (a MD technique error). There were only two instances of mine simulants identified as clutter during the Retention Test. The low rates of simulant misidentification as clutter (0 and 2 at Exit and Retention Test, respectively) combined with the low clutter rejection at both Exit and Retention suggests that GPR technique was ineffective but

corrected for by a strong decision bias to call any detected target a mine simulant. Therefore, these data may not be able to provide information about degradation in GPR technique.

An analysis of the two types of mine simulant detection errors identifed above revealed no significant increase in "failure to find" errors. That is, the mean number of detection errors that occurred because no chip was placed on or near the mine simulant did not increase between Exit and Retention Tests, M = 0.21 and 0.29, respectively, $t\ (48) < 1$. Failures to accurately identify the center of the mine simulant did increase. The mean number of detection errors that occurred because a chip was placed too far from the mine simulant center did increase between Exit and Retention, M = 0.29 and 1.06, respectively, $t\ (48) = 4.19, p < 0.001$.

To further assess this degredation of MD technique, an analysis of the accuracy of mine simulant centering was conducted. This analysis included detected simulants, only. Thus any simulant which was not detected was not included. Figure 11 shows the mean distance of poker chip placement from mine simulant center at Exit and Retention for the three Retention Interval groups. Higher scores represent worse performance.

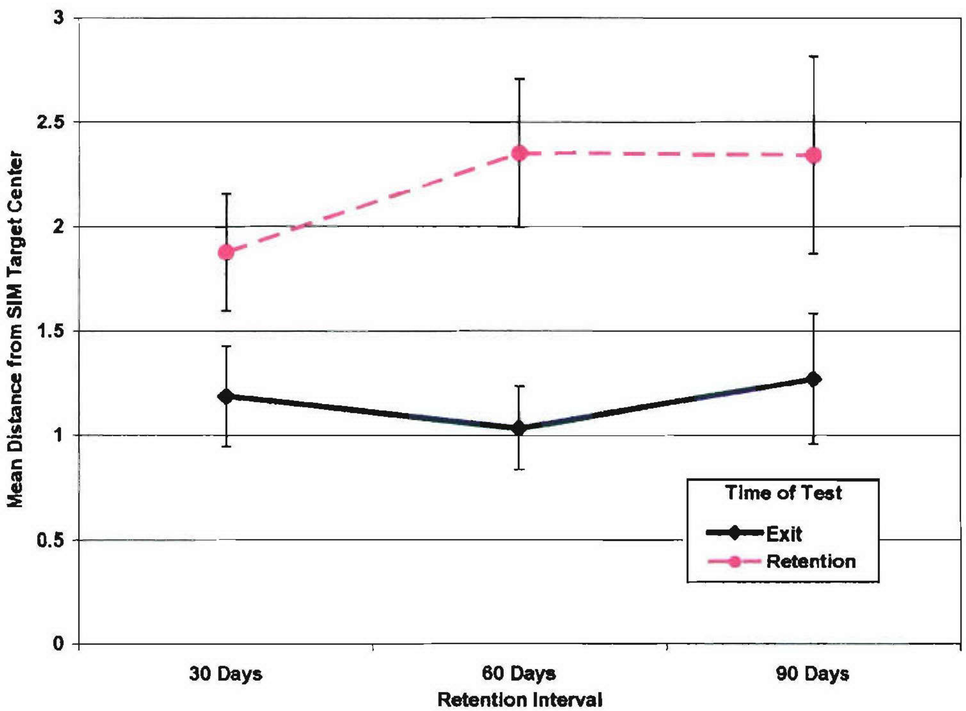


**Figure 11 Average distance from mine simulants centers to poker chip marker by time of test and retention interval (with 95% confidence interval bars).**

Consistent with the visual impression, ANOVA (see Table 5) revealed significant decrements in proportion of mine simulants detected due to Time of Test ($p < .0001$). Overall, Retention Test performance was worse than Exit Test performance. In addition, the differential effect of retention interval, as evidenced by the Retention Group x Time of Test (Exit vs. Retention)

interaction, was marginally significant ($p$ = .0624). Confirming the visual impression, a protected *t-test* revealed a significant increase in mean distance between the 30 Days and 60 Days Retention Tests, $t$ (45) = 4.28 ($p < .0001$), and no further changes at 90 Days, $t$ (45) < 1.00 ($p > 0.50$).

Due to sample size constraints, three factors which, *a priori*, were deemed to be important to detection of mines, i.e., Mine Composition (high vs. low metal), Mine Size (anti-tank vs. anti-personnel), and Halo Overlap (absence of overlapping metal halo from nearby clutter and presence of overlapping metal halo from nearby clutter) could not be fully balanced. Therefore, analyses of these factors were undertaken in isolation and in pairs. Analyses which showed signficiant effects are presented here.

Mine Composition had a significant effect on the likelihood of detection. As Figure 12 shows, High Metal Mine Simulants were more likely to be detected than Low Metal Mines Simulants at Exit and Retention.

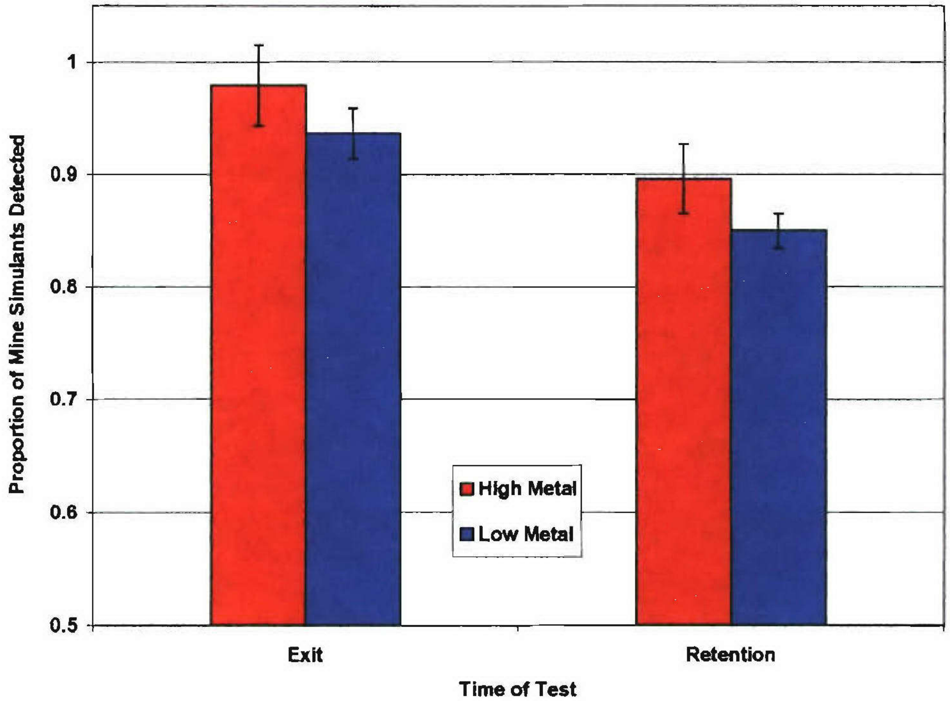


**Figure 12 Mean proportion of high metal and low metal simulants detected (with 95% confidence interval bars).**

Consistent with the visual impression of Figure 12, ANOVA of Retention Group (RG), Metal Composition (MC) and Time of Test (TT) revealed significant main effects of Mine Composition ($p < 0.05$) and Time of Test ($p = 0.001$) on proportion of mine simulants detected (see Table 6). All other main effects and interaction were not significant ($p > 0.20$).

As expected High Metal mine simulants were readily detected. *A priori*, Low Metal mine simulants because of their greater difficulty in detection were expected to be most sensitive to the effects of of other variables. Therefore, an analysis of the effects of Retention Group, Mine Size, and Halo Overlap on Detection of Low Metal Mine Simulants, only, was conducted. Figure 13 shows the results of that analysis.

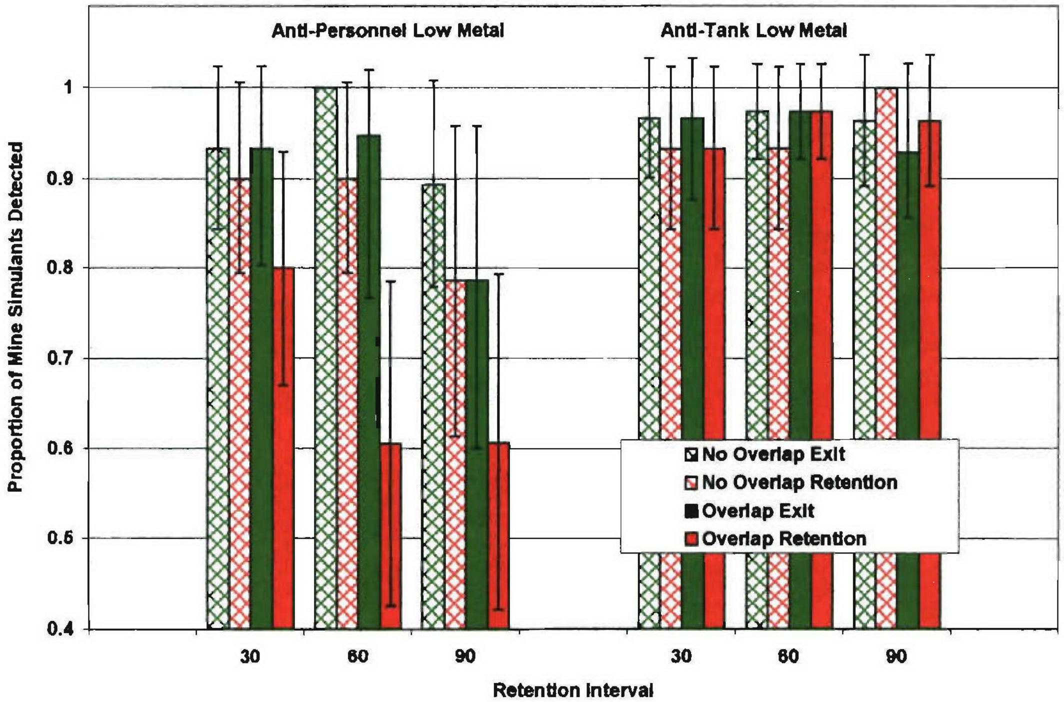


**Figure 13 Mean proportion of low metal mine simulants detected by retention group, mine size, halo overlap and time of test (with 95% confidence interval bars).**

The visual impression suggests the possibility of a 4-way Retention Group x Mine Size x Halo Overlap x Time of Test interaction, but this interaction was not significant ($F < 1.00$) because of large variation in performance in Halo Overlap conditions, particularly during Retention Testing. Table 7 contains the ANOVA summary table for this 4-variable analysis.

However, as Table 7 indicates and the visual impression of Figure 14 below shows, a marginally significant 3-way interaction of Mine Size x Halo Overlap x Time of Test was found. APLMs that had overlapping halos with adjacent clutter became significantly more difficult to detect on the Exit Test at all Retention Intervals. Again, note the large variability in the rate of detecton of APLMs with Halo Overlap on the Exit Test compared to all other conditions. This variability is most likely due to the very small sample size ($n$ = 1 or 2) of APLMs with Halo Overlap for each research participant.

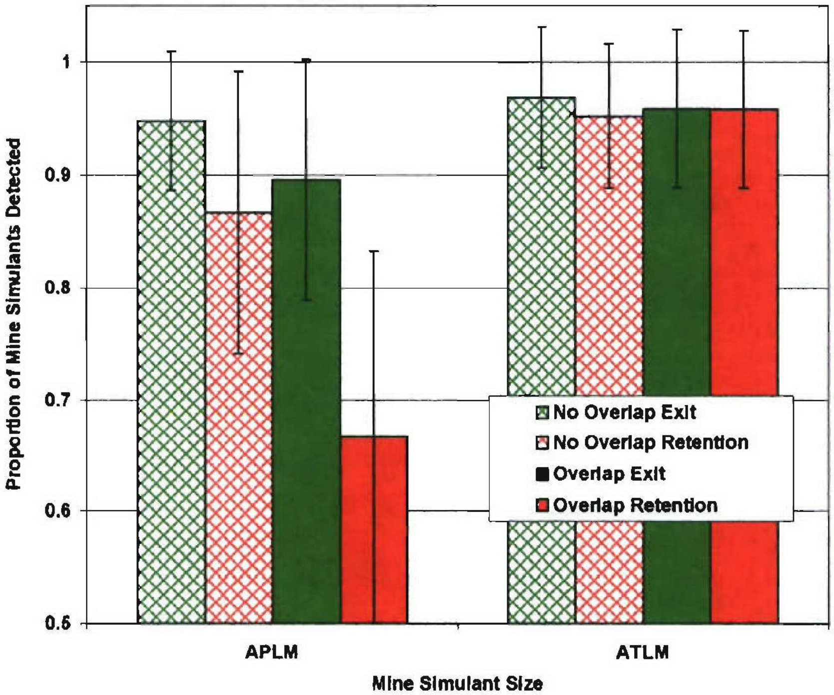


**Figure 14 Mean proportion of detection of low metal mine simulants by mine size, halo overlap, and time of test (with 95% confidence interval bars).**

## 3.5 Other Results

There were two other results of note. The first was a GPR anonomly that was recurrent but not repeatable. That is, SIM 6s in the sand pits and some tactical lanes failed to produce GPR output from the AN/PSS-14 on some occassions which were unpredictable and uncontrollable.

The second result of note was the performance on two high clutter tactical lanes by a Cyterra expert. Because of the GPR anomoly, two Cyterra engineers visited the training site. One of these engineers is identified by CyTerra as an expert in the use of the AN/PSS-14. This Cyterra identified expert swept two tactical lanes. The Cyterra expert found 78 out of 78 targets (mine simulants and clutter), correctly identified all 18 mine simulants, and correctly rejected 59 out of the 60 pieces encountered.

# 4. Experiment 2 – Method & Results

## 4.1 Brief Introduction

The low metal mine simulants currently employed by the U.S. Army to generate high fidelity auditory responses from the AN/PSS-14 handheld mine detector during intial training and refresher training are extremely expensive, approximately $600 per low metal SIM. (The high metal mine simulants are easy and inexpensive to manufacture.) The expensiveness of current low metal SIMs unnecessarily inflates the cost of current training and discourages some research on the AN/PSS-14 and AN/PSS-14 training as researchers and trainers are reluctant to use expensive mine simulants, for which researchers and trainers may be held accountable. In Experiment 2, an inexpensive set of low metal land mine simulants were developed and tested by the Center for Environmental Science and Technology of the University of Missouri - Rolla (CEST) under a sub-contract from Lincoln University.

Initial U.S. Army specifications for low metal mine simulants identified physical but not performance characteristics for the simulants. The physical characteristics specified included the simulant body composition, the exterior size and shape, Dow Corning RTV 3110 Silicone as filler for the simulant body, and the ability to insert a small carbon steel pin and/or a small aluminum tube. The RTV filler and metal pieces were known to appear to the AN/PSS-14 detector sensors much like actual mines. The metal components that reliably replicate low metal mines and thus yield high fidelity auditory signals from the AN/PSS-14's metal detector have been validated, are readily available, and inexpensive; however, the body filler is quite expensive. Therefore, this experiment sought to develop high-fidelity land mine simulants from the metal components of current mine simulants but with inexpensive off-the-shelf components for the mine simulant body and body filler.

## 4.2 Method & Results

Based upon their knowledge of material engineering, metal detection, and ground penetrating radar, the CEST developed a set of low metal mine simulants from currently used metal components and off-the-shelf body parts and filler. The CEST was able to create SIMs matching the physical dimensions of the current U.S. Army simulant set which consists of, one each, SIM 6, 9, 12, 20, 25, and 30 at the approximate manufactured cost of $60 per SIM.

As performance specfications for mine simulants were lacking, the CEST developed a technique for recording AN/PSS-14 MD and GPR output from U.S. Army and CEST SIMs. An AN/PSS-14 was mounted on a rotating arm located in the center of a control test environment. The control test environment consisted of an approximately 1.8 M diameter tub filled with sand mounted 0.5 M above ground level. Both the rotating arm and test environment were free of metal parts with the arm rotated by a non-metalic belt attached to a remote reversible and variable speed motor. An Edirol R-1 24bit digital Wave/MP3 recorder was mounted on the

AN/PSS-14 to record audio outputs of the MD and GPR systems. Figure 15 shows three views of the AN/PSS-14 mounted on the rotating arm in the control test environment.

**Figure 15 Three views of CEST control test environment.**

The AN/PSS-14 was ground balanced and GPR trained over the sand of the control test environment with the detector head parallel to and just above ground level. Individually, U.S. Army and CEST SIMs were buried at depth. Six passes of the detector head were made over each of the 12 targets. The recorded signatures were then downloaded onto a computer and analyzed in Adobe Audition 1.5 for comparison. This yielded visual displays of GPR response per unit of time. GPR responses varied slightly with each detector head pass. The detector head pass that generated the most continuous signal response (fewest breaks in GPR return signal) for each simulant was used to make comparisons between simulants. Figures 16 and 17 show the best GPR response to U.S. Army and CEST APLMs and ATLMs, respectively. Deflections up and down from the horizon represent GPR signals. Note that the amplitude of the GPR is relatively constant. Strength of the GPR output is represented by the frequency of the signal or, in these figures, the density of up-down lines.

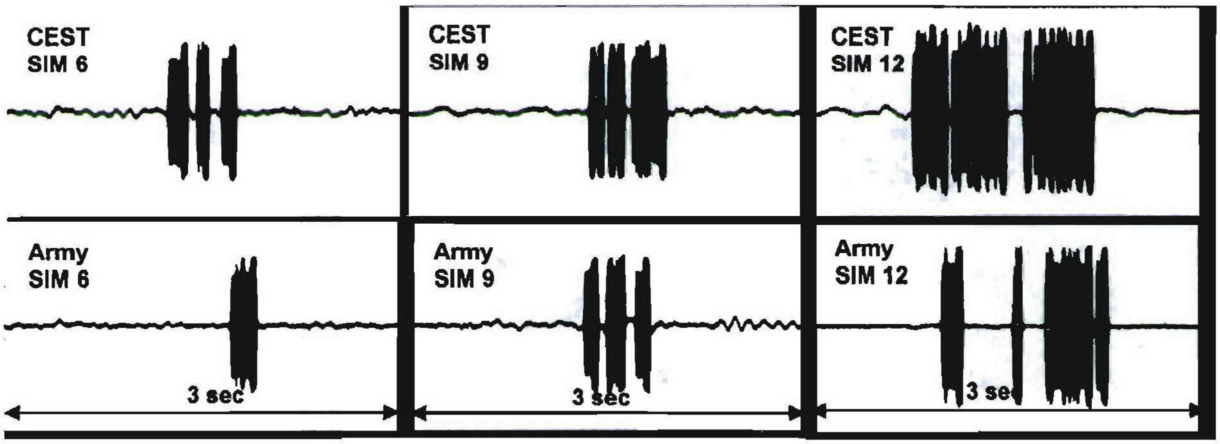


**Figure 16 GPR response to U.S. Army and CEST Anti-Personnel Low Metal mine simulants.**

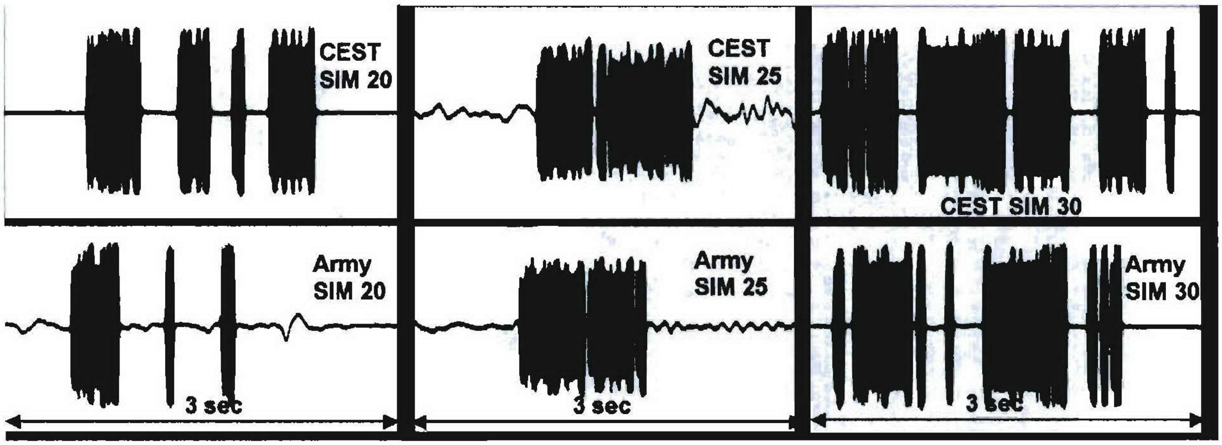


**Figure 17 GPR response to U.S. Army and CEST low metal anti-tank mine simulants.**

Visual inspection of GPR outputs makes it quite clear that the CEST simulants produce more robust GPR signals than current U.S. Army simulants.

## 5. General Discussion

From Experiment 1, the following conclusions emerge. One, at the end of training, research participants could reliably detect mine simulants. Two, at the end of training, research participants could not reliably reject clutter. Three, analyses of Retention Test data indicated that the MD technique necessary to detect mine simulants decayed rapidly. Four, mine simulant detection decay was markedly different for a specific combination of mine type and clutter presence.

One, on the Exit Test at the end of training, Research participants had a median probability of mine simulant detection of 1.00 indicating that these participants were clearly able to employ the AN/PSS-14 to detect land mine simulants. The participants were able to perform Sweep, MD, and GPR techniques sufficiently well to meet U.S. Army certification standards.

Two, although able to detect mine simulants at the end of training, research participants were unable to reliably reject clutter. There are numerous possibilities for their failure to reliably reject clutter. One, the POI may not be teaching correct GPR technique. Two, the participants might not have been able to execute correct technique. Three, there may be inherent limitations in the capabilities of AN/PSS-14 to reject certain types of clutter. Current data do not allow for the determination of which of these possibilities is the most likely.

Retention Test data clearly indicate rapid forgetting of mine detection skill as there was a significant decrease in the proportion of mine simulants detected as early as 30 days after training. No evidence of declines in Sweep technique emerged. Clear evidence emerged that MD technique was especially sensitive to forgetting. Thirty days after training, there was a signficant decrease in chip centering with a further decrease at 60 days after training.

The combination of high mine simulant detection rates with low clutter rejection rates on the Exit Test at the end of training makes analysis of changes in GPR technique on the Retention Test problematic. Loss (or forgetting) of GPR technique could have been evidenced by either significant changes in clutter rejection or a marked increase in identification of mine simulants as clutter on the Retention Test. Neither occurred. Clutter rejection was probably too low on the Exit Test, a "floor effect", and misidenfication of mine simulants as clutter too infrequent (a total of two) to detect differences. However, the failure to detect clear evidence of changes in GPR technique could also have been due to a strong decision bias on the part of trainees to call detected targets mines.

Evidence that mine detection skill loss could have serious consequences was clear. Low metal anti personnel mine simulants whose MD halos overlapped clutter MD halos were detected approximately 67% of the time on the Retention Test. The approximately 33% error rate was due primarily to "distance errors", i.e., placing a poker chip well off the mine body.

This clear demonstration of the sensitivity of MD technique to rapid forgetting and its consequences indicates that both the Certification criteria and the POI implemented in this study need significant change. Training lanes should include more Anti-Personnel Low Metal mine simulants with metal halo overlap as these are the most challenging mine simulants and mines to detect accurately. The POI for the AN/PSS-14 should have increased emphasis on MD technique and detection of low metal simulants with halo overlap.

From Experiment 2, the following conclusion emerges. It is possible to produce significantly lower cost high fidelity low metal land mine simulants. Validation of all land mine simulants against actual land mines needs to be undertaken to insure that trainees are being trained against an appropriate standard.

## References


Fan, M. J. (1987). The long-term retention of knowledge and skills: A cognitive and instructional perspective. Springer-Verlag: New York, NY.

Healy, A. F. & Bourne, L. E. (1995). Learning and memory of knowledge and skills: Durability and specificity. Sage Publications: Thousand Oaks, CA.

Maurer, L. (2003). AN/PSS-14 Mine Detector Assessment for Operation Enduring Freedom. USAES Trip report.

Rose, A. M., Czamolewski, M. Y., Gragg, F. E., Austin, S. H., Ford, P., Doyle, J., & Hagman, J. D. (1985). Acquisition and retention of soldiering skills. U. S. Army Research Institute for Behavioral and Social Science Technical Report #671.

Santiago, A., Locke, M., & Reidy, D. (2004). Operational test results for the AN/PSS-14 (HSTAMIDS). Proceedings of the UXO/Countermine Forum, 9-12 March 2004, St. Louis, MO.

Schweitzer, K. M., Davis, B. M., Pettijohn, B. A., Clark, R. D., Davison, A. D., & Staszewski, J. J. (2006). Optimization of AN/PSS-14 Operator Training, in preparation.

Shields, J. L., Goldberg, S. L., & Dressel, J. D. (1979). Retention of basic soldering skills. U. S. Army Research institute for Behavioral and Social Science Research Report #1225.

Tukey, John (1977). *Exploratory Data Analysis.* Addison-Wesley: New York, NY

## Footnotes

1. Major parts of this section were paraphrased from Schweitzer et al. (2006).
2. Analyses with these four subjects included available on request.

**Table 1**

*AN/PSS-14 Start Procedure*

| Step 1 | | Step 2 | | Step 3 | | Step 4 | | Step 5 | |
|---|---|---|---|---|---|---|---|---|---|
| **Power up** | | **Noise Cancel** | | **Ground Balance** | | **GPR Training** | | **Verification with Test Piece** | |
| 1.1 | Raise detector 1-2 ft above ground | 2.1 | Lower sensor head to ground | 3.1 | Position sensor head | 4.1 | Take stance | 5.1 | Set GPR sensitivity switch |
| 1.2 | Set GPR sensitivity | 2.2 | Call "Noise Cancel" | 3.2 | Push and hold Cal switch | 4.2 | Position sensor head | 5.2 | Place test piece on ground |
| 1.3 | Push power switch | 2.3 | Push Noise Cancel switch | 3.3 | Up-down procedure until completion | 4.3 | Begin sweep | 5.3 | Conduct GPR Short Sweep (SS) |
| 1.4 | Recognize BIT failure, if it occurs | 2.4 | Recognize process completion | 3.4 | Release Cal switch and continue one cycle | 4.4 | Continue with proper technique | 5.4 | Repeat GPR SS with MD only |
| 1.5 | Recognize process completion | 2.5 | Call "Noise Cancel Complete" | 3.5 | Recognize process completion | 4.5 | Release trigger | 5.5 | Repeat GPR SS with PR only |
| | | | | | | 4.6 | Recognize process completion | 5.6 | Set to MIN, repeat GPR SS |
| | | | | | | 4.7 | Complete sweep movement | 5.7 | Set to MAX, repeat GPR SS |
| | | | | | | | | 5.8 | Set to 12 o'clock, repeat GPR SS |

**Table 2**

*Outline of AN/PSS-14 Certification Training Program of Instruction (POI)*

| | | TITLE | LOCATION |
|---|---|---|---|
| DAY 1 | 0845-0900 | Introductions/Administrative Information | Classroom |
| | 0900-0930 | Lesson 1-Introduction and Theory | Classroom |
| | 0930-1030 | Lesson 2-Prepare for Operation (PMCS) | Classroom/PE |
| | 1030-1100 | Lesson 3-Controls and Audio Indicators | Classroom |
| | 1100-1200 | Lesson 4-Sweep Technique | Sweep Training Area |
| | 1200-1300 | Lunch | Classroom |
| | 1300-1430 | Lesson 4-Sweep Technique (cont) | Sweep Training Area |
| | 1430-1530 | Lesson 5-Calibration | Sweep Training Area |
| | 1530-1545 | Lesson 6a-Footprints | Sterile Sand Pits |
| | 1545-1605 | Lesson 6b-Footprints | Sterile Sand Pits |
| | 1605-1735 | Lesson 6c-Footprints | Sterile Sand Pits |
| | 1735-1745 | Lesson 7-Repack | Classroom |
| | 1745-1800 | Review | Classroom |
| DAY 2 | 0845-0900 | PMCS-Review | Classroom |
| | 0900-1030 | Lesson 6c-Footprints (cont) | Tactical Training Area |
| | 1030-1230 | Lesson 6d-Footprints | Tactical Training Area |
| | 1230-1330 | Lunch | Classroom |
| | 1330-1500 | Lesson 6e-Footprints | Tactical Training Area |
| | 1500-1745 | Practical Exercise | Tactical Training Area |
| | 1745-1800 | PMCS-Review | Classroom |

| | | | |
|---|---|---|---|
| DAY 3 | 0845-0900 | PMCS-Review | Classroom |
| | 0900-1200 | Practical Exercise | Tactical Training Area |
| | 1200-1300 | Lunch | Classroom |
| | 1300-1745 | Practical Exercise | Tactical Training Area |
| | 1745-1800 | PMCS-Review | Classroom |
| DAY 4 | 0845-0900 | PMCS-Review | Classroom |
| | 0900-1200 | Practical Exercise | Tactical Training Area |
| | 1200-1300 | Lunch | Classroom |
| | 1300-1745 | Practical Exercise | Tactical Training Area |
| | 1745-1800 | PMCS-Review | Classroom |
| DAY 5 | 0900-1000 | Written Test and Review | Classroom |
| | 1000-1015 | PMCS | Classroom |
| | 1015-1200 | Field Performance Test | Tactical Training Area |
| | 1200-1300 | Lunch | Classroom |
| | 1300-UTC | Field Performance Test | Tactical Training Area |
| | TBD | Inventory | Classroom |
| | TBD | After Action Review | Classroom |
| | TBD | Graduation | Classroom |

**Table 3**

***Sample Size (N), Mean, Standard Deviation (Std Dev), and Standard Error (Std Error) of the Proportion of Mine Simulants Detected by Retention Group (RG) and Time of Test (Exit & Retention)***

| | N | Mean | Std Dev | Std Error |
|---|---|---|---|---|
| **RG=30** | | | | |
| **Exit** | 15 | 0.941 | 0.057 | 0.015 |
| **Retention** | 15 | 0.881 | 0.115 | 0.030 |
| **RG=60** | | | | |
| **Exit** | 19 | 0.977 | 0.047 | 0.011 |
| **Retention** | 19 | 0.836 | 0.163 | 0.037 |
| **RG=90** | | | | |
| **Exit** | 14 | 0.905 | 0.096 | 0.026 |
| **Retention** | 14 | 0.833 | 0.121 | 0.032 |

**Table 4**

***ANOVA Summary Table for Proportion of Mine Simulants Detected by Retention Group (RG) and Time of Test (Exit & Retention)***

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Retention Group (RG) | 2 | 0.03123221 | 0.0156161 | 1.2 | 0.3108 |
| Error | 45 | 0.58592314 | 0.01302051 | | |
| Within Subjects | | | | | |
| Time of Test (TT) | 1 | 0.1925843 | 0.1925843 | 18.32 | <.0001 |
| TT * RG | 2 | 0.03300825 | 0.01650413 | 1.57 | 0.2192 |
| Error(trial) | 45 | 0.47303599 | 0.0105119 | | |

**Table 5**

***ANOVA Summary Table for Mean Distance Between Mine Simulant Center and Poker Chip Target marker by Retention Group (RG) and Time of Test (Exit & Retention)***

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Retention Group (RG) | 2 | 1.12314269 | 0.56157135 | 1.07 | 0.3518 |
| Error | 45 | 23.63076003 | 0.52512800 | | |
| Within Subjects | | | | | |
| Time of Test (TT) | 1 | 24.95929367 | 24.95929367 | 89.60 | <.0001 |
| TT * RG | 2 | 1.64448321 | 0.82224161 | 2.95 | 0.0624 |
| Error(trial) | 45 | 12.53513589 | 0.27855858 | | |

**Table 6**

***ANOVA Summary Table for Mean Proportion of Mine Simulants Detected by Retention Group (RG), Metal Composition of Mine Simulant (MC) and Time of Test (Exit & Retention)***

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Retention Group (RG) | 2 | 0.01511934 | 0.00755967 | 0.32 | 0.7296 |
| Error | 45 | 1.07136069 | 0.02380802 | | |
| Within Subjects | | | | | |
| Metal Composition (MC) | 1 | 0.09616852 | 0.09616852 | 4.30 | 0.0439 |
| MC * RG | 2 | 0.04887561 | 0.0244378 | 1.09 | 0.3440 |
| Error | 45 | 1.00635443 | 0.02236343 | | |
| Time of Test (TT) | 1 | 0.31602775 | 0.31602775 | 12.45 | 0.0010 |
| TT * RG | 2 | 0.04331249 | 0.02165625 | 0.85 | 0.4329 |
| Error | 45 | 1.14230672 | 0.02538459 | | |
| MC * TT | 1 | 0.00000028 | 0.00000028 | 0.00 | 0.9971 |
| MC * TT * RG | 2 | 0.01961784 | 0.00980892 | 0.49 | 0.6185 |
| Error(MC * TT) | 45 | 0.90905693 | 0.02020127 | | |

**Table 7**

***ANOVA Summary Table for Mean Proportion of Low Metal Mine Simulants Detected by Retention Group (RG), Mine Size (MS), Halo Overlap (HO), and Time of Test (Exit & Retention)***

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Retention Group (RG) | 2 | 0.1905 | 0.0952 | 1.68 | 0.1969 |
| Error | 45 | 2.5433 | 0.0565 | | |
| Within Subjects | | | | | |
| Mine Size (MS) | 1 | 1.4604 | 1.4604 | 29.16 | <.0001 |
| MS * RG | 2 | 0.2772 | 0.1386 | 2.77 | 0.0735 |
| Error | 45 | 2.2534 | 0.0501 | | |
| Halo Overlap (HO) | 1 | 0.34 | 0.34 | 9.79 | 0.0031 |
| HO * RG | 2 | 0.062 | 0.031 | 0.89 | 0.4164 |
| Error | 45 | 1.5623 | 0.0347 | | |
| Time of Test (TT) | 1 | 0.6217 | 0.6217 | 15.95 | 0.0002 |
| TT * RG | 2 | 0.1314 | 0.0657 | 1.69 | 0.1968 |
| Error | 45 | 1.7534 | 0.039 | | |
| MS * HO | 1 | 0.2602 | 0.2602 | 6.66 | 0.0132 |
| MS * HO * RG | 2 | 0.0488 | 0.0244 | 0.63 | 0.5398 |
| Error (MS * HO) | 45 | 1.7578 | 0.0391 | | |
| MS * TT | 1 | 0.5679 | 0.5679 | 11.65 | 0.0014 |
| MS * Time of Test * | 2 | 0.1492 | 0.0746 | 1.53 | 0.2275 |
| Error (MS * TT) | 45 | 2.1939 | 0.0488 | | |
| HO * TT | 1 | 0.0711 | 0.0711 | 1.70 | 0.1990 |
| HO * TT * RG | 2 | 0.0081 | 0.0041 | 0.10 | 0.9077 |
| Error (HO * TT) | 45 | 1.8819 | 0.0418 | | |
| MS * HO * TT | 1 | 0.0956 | 0.0956 | 2.95 | 0.0930 |
| MS * HO * TT * RG | 2 | 0.0229 | 0.0115 | 0.35 | 0.7045 |
| Error (MS * HO * TT) | 45 | 1.4608 | 0.0325 | | |

## Alphabetical List of Acronyms

| Acronym | Meaning |
|---|---|
| ANOVA | Analysis of Variance |
| APLM | Anti-Personnel Low Metal Mine |
| APM | Anti-Personnel (High) Metal Mine |
| ASVAB | Armed Services Vocational Aptitude Battery |
| ATLM | Anti-Tank Low Metal Mine |
| ATM | Anti-Tank (High) Metal Mine |
| CEST | Center for Environmental Science and Technology of the University of Missouri - Rolla |
| DOTLD | Directorate of Training and Leader Development |
| GPR | Ground Penetrating Radar |
| MC | Metal Composition |
| MD | Metal Detector |
| NET | New Equipment Training |
| ORD | Operational Requirements Document |
| PMCS | Preparation for Operation of the AN/PSS-14 |
| POI | Program of Instruction |
| RG | Retention Group |
| ROTC | Reserve Officer Training Corps |
| SIM/s | Land Mine Simulant |
| SMS | Sweep Monitoring System |
| SS | Short Sweep for GPR |
| TRADOC | Training and Doctrine Command |
| TT | Time of Test |